A millimeter/submillimeter heterodyne sensor for spectroscopy and imaging of cold planetary objects in the outer solar system

Completed Technology Project (2018 - 2021)

Project Introduction

We propose to develop a tunable millimeter/submillimeter-wave antenna coupled graphene mixer-based heterodyne sensor on future missions to icy moons (Titan, Enceladus, and Europa) of the outer planets of our solar system. The proposed technology is focused on the "Ocean Worlds" mission theme and will enable to address challenge questions - significance of abiological synthesis of organics, i.e., hydrocarbons, their derivatives, and ions (carbocations and carbanions) - in the origin of life on Earth. Investigating this abiotic chemistry is a necessary step in the quest to understand the origin of life and habitability context. The goal of planetary exploration research is the identification of molecules of prebiotic importance (e.g. the aromatic rings, heterocycles, nucleic acid bases, and amino acids) in space through rotational spectroscopy, and the elucidation of their chemical structures using the proposed heterodyne detection technique. The detector system is based on non-linear 2 wave mixing of the weak THz radiation and a THz local oscillator in a graphene photo-thermo-electric detector (Cai et al., Nature Nanotechnology 9(10) 814 (2014)). This results in a heterodyne response for the weak THz signal with the difference frequency relative to the local oscillator. The noise temperatures of noncryogenic graphene mixers are expected to fall between respective values of superconducting SIS heterodyne detectors and hot electron bolometer HEB square law mixers and require less local oscillator power than Schottky diode mixers. We expect to bring this technology from TRL1 to TRL4. Besides hydrogen and water (as water ice), methane and methanol constitute as the major molecular matter in our solar system. We identified "Olah's nonclassical carbonium ion chemistry" as preferred chemical pathway for abiotic synthesis of organic compounds on Titan, and this pathway begins by the conversion of most abundant methane to methonium ion CH5+ (Ali et al., P & SS, 109-110 (2015) 46; Puzzarini et al., AstronJ. 154: 82(2017)). Because of the observed higher reactivity of methanol with respect to methane, a feasible new pathway has recently been proposed for the conversion of methanol to various extraterrestrial abiological organics together with a possible connection with methonium ion-based chemistry (Olah et al., JACS. 138 (2016) 1717). If methanol (a derivative of methane) indeed has been delivered by meteorites or comets to the icy surface of Europa in the chemistry of formation of our solar system, it is suggested that the radiation- catalyzed surface chemistry of Europa could also mimic the observed prebiotic chemistry on Titan by the Cassini-Huygens mission. Rotational spectroscopy in space from future orbiting spacecrafts (Titan and Europa Orbiter) would provide important information of atmospheric and surface-assisted prebiotic chemistry using the proposed heterodyne sensor. On the detection of any biological process or chemical markers for extraterrestrial life, spectroscopy of representative building blocks of life in the Ocean Worlds of the outer solar system (e.g. spectrum of Enceladus plume composition) is an important step. The proposed graphene mixer-based sensor will also enable the measurements of winds with high velocity resolution from Doppler shift studies of optically thin rotational lines.

Image Not Available

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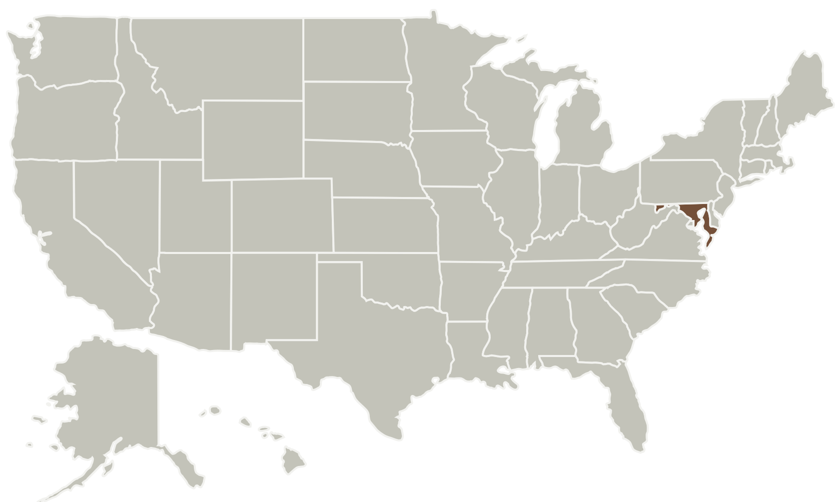
In addition, this technology will permit a sensitive array receiver configuration for thermal imaging of surfaces of cold planetary bodies in the outer solar system with spectral resolution. A major breakthrough in technical challenges on the design and development of the sensor proposed will put studies of spectroscopy, chemistry and dynamics of the environments of icy moons of outer planets in our solar system, and will provide a lasting impact on the "relevance and significance of extraterrestrial abiological hydrocarbon chemistry" in the origin of life as stated in the Planetary Science Decadal Survey (2013-2022).

Anticipated Benefits

The sensor will be used on future missions to the icy moons (Titan, Enceladus, and Europa) of the outer planets of our solar system. The proposed technology is focused on the "Ocean Worlds" mission theme and will enable to address challenge questions - significance of abiological synthesis of organics, i.e., hydrocarbons, their derivatives, and ions (carbocations and carbanions) - in the origin of life on Earth

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

University of Maryland-College Park (UMCP)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

Howard D Drew

Co-Investigators:

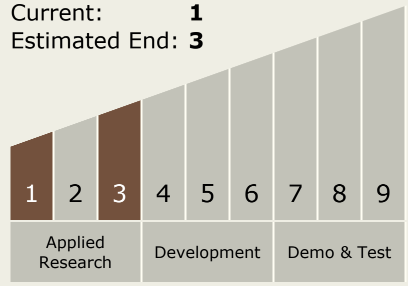
Thomas E Murphy
Ashraf - Ali
Gregory S Jenkins
Cristina Puzzarini
Katie M Mckeon

Organizations Performing Work	Role	Type	Location
University of Maryland-College Park(UMCP)	Lead Organization	Academia Asian American Native American Pacific Islander (AANAPISI)	College Park, Maryland
University of Bologna	Supporting Organization	Academia	

Primary U.S. Work Locations
Maryland

Technology Maturity (TRL)

Start: **1**
Current: **1**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.4 Microwave, Millimeter-, and Submillimeter-Waves

Target Destination

Others Inside the Solar System